Investigation of Fe$_3$O$_4$ core/ mesoporous SiO$_2$ shell microspheres based on Mössbauer spectroscopy.

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Introduction

Recently, magnetic iron oxide nanoparticles have been considered to be an ideal candidate for biological application, both as a tag for sensing and imaging, and as an activity agent for antitumor therapy[1, 2]. The requirements for any biomedical application of magnetic colloids include the chemical stability, biocompatibility. Magnetic microspheres consisting of Fe$_3$O$_4$@SiO$_2$ core-shell have attracted attention as bio/medical application for its low coercivity, high saturation magnetization, and chemically stabilization[2, 3].

In this paper, we have studies the magnetic properties and hyperfine interaction of Fe$_3$O$_4$ and Fe$_3$O$_4$ core/SiO$_2$ shell, investigated with the magnetization curve and Mössbauer spectroscopy experiment.

Experiment

The Fe$_3$O$_4$ core and Fe$_3$O$_4$ core/mesoporous SiO$_2$ shell microspheres were prepared by a solvothermal reaction method. The crystal structure of the sample was examined by X-ray diffraction(XRD) with CuK$\alpha$ ($\lambda$= 1.540562 Å) radiation. The size and shape of the products were examined by high-resolution transition electron microscopy(HR-TEM). The magnetic properties were characterized using a vibrating sample magnetometer(VSM) and Mössbauer spectroscopy. Mössbauer spectra of Fe$_3$O$_4$ and Fe$_3$O$_4$ core/SiO$_2$ shell were recorded from 4.2 K up to room temperature with a $^{57}$Co source in Rh matrix.

Results and discussion

The crystal structure of Fe$_3$O$_4$ core was determined by the Rietveld refinement technique. The crystal structure of the Fe$_3$O$_4$ core was cubic structure of $Fd-3m$ with lattice constant $a_0$ = 8.395 Å. The Fe$_3$O$_4$ core/SiO$_2$ shell structure was confirmed by TEM as shown in Fig. 1. According to the measurement for magnetization curves at room temperature, the saturation magnetization of Fe$_3$O$_4$ and Fe$_3$O$_4$ core/SiO$_2$ shell microspheres are determined to be 77.0 and 17.0 emu/g, respectively. The Mössbauer spectra for the samples were analyzed of two six-line hyperfine patterns. The fitted data apparently verified that the prepared Fe$_3$O$_4$ and Fe$_3$O$_4$ core/SiO$_2$ shell samples have magnetite [Fe$^{3+}$$_4$][Fe$^{2+}$Fe$^{3+}$]$_{16}$O$_{44}$. It is noticeable that the Mössbauer absorption area ratio between tetrahedral A($8a$) and octahedral B($16d$) site of the Fe$_3$O$_4$ core/SiO$_2$ shell shows enormous change compare with that of Fe$_3$O$_4$. The A and B site the area ratio of sextet increase from 40 : 60 to 55 : 45 for Fe$_3$O$_4$ and Fe$_3$O$_4$ core/SiO$_2$ shell, respectively, at room temperature. The magnetic hyperfine fields of A and B site in Fe$_3$O$_4$ are $H_{hf}$(A) = 517 kOe and $H_{hf}$(B) = 493kOe, and Fe$_3$O$_4$ core/SiO$_2$ shell spheres are $H_{hf}$(A) = 519 kOe and $H_{hf}$(B) = 511 kOe, at 4.2 K. Hyperfine fields of A and B site in Fe$_3$O$_4$ core/SiO$_2$ shell spheres are $H_{hf}$(A) = 486 kOe and $H_{hf}$(B) = 449 kOe, at room temperature, as shown in Fig. 2.